

Comment on "Conventional superconductivity at 203 kelvin at high pressures in the sulfur hydride system"(A. P. Drozdov et al., Nature 525, 73 (2015))

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It is demonstrated that resistive transition at 203 K observed in metallic sulfur hydride system at high pressure [1] can be magnetic (rather than superconducting (SC)) in nature. The onset temperature of genuine superconducting transition in these compounds appears to be essentially lower on temperature. The normal-state magnetic (AF SDW) phase transition preceding a superconducting one ($T_c < T_m$) is characteristic for HTSC cuprates, pnictides (selenides) and organic superconductors. The resistive drop is provided by disappearing of magnetic (AF spin fluctuation) scattering of conduction electrons and hence formation of AF SDW order in the normal state. The formation of such modulated magnetic structure in sulfur hydride seems to be possible because of magnetic properties of metallic hydrogen at high densities (in analogy with iron). Such unconventional picture with two successive phase transitions: magnetic (AF SDW) and only then superconducting one is naturally described by Keldysh-Kopaev theory of dielectric (metal-insulator) phase transition in systems with coexistence of superconducting (e-e) and dielectric (e-h) pairings.

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In a recent literature, there was claimed about significant progress towards room temperature superconductivity in sulfur hydrides at high pressure ("conventional superconductivity at 203 K"[1], see also [2]). The conclusion about superconducting nature of resistive transition at 203 K was made on the basis of both sharp drop of resistivity below 203 K up to nearly zero and shift of so-defined "onset temperature" towards zero with magnetic field. The decrease of paramagnetic magnetization beginning at the same temperature ($\sim 203K$) was considered in [1] as supporting fact for superconducting nature of resistive transition. The noticeable shift of resistive transition due to isotope effect under replacing of deuterium instead of hydrogen permits them conclude about conventional (phonon) nature of so-defined superconducting mechanism. However, such formal attributes being necessary are not sufficient for resistive transition to be superconducting.

As known, the thermodynamics of Keldysh-Kopaev (KK) dielectric (metal-insulator) phase transition [3] is the same as that for superconductor. And in systems with coexistence of dielectric (e-h) and superconducting (e-e) pairings superconducting transition is preceded by dielectric phase transition ($T_c \leq T_D$). In such case, the dielectric gap Σ is first opened at symmetrical parts of the Fermi surface, and only at lower temperature the superconducting gap Δ opens at the rest part of the Fermi surface. In result, below critical temperature of superconducting transition T_c two different in nature gaps coexist with one other in electron energy spectrum. The KK dielectric transition provides some rise of critical temperature of SC transition due to increase of electron density of states (DOS) at the edges of

dielectric gap due to removing of electronic states from the energy region of dielectric gap. Such mechanism for rise of T_c remains to be phonon (but not conventional!) in nature [4]. The sequence of two successive phase transitions: dielectric and only then superconducting ($T_c < T_D$) is in fact realized in high- T_c cuprates [5, 6], and organic superconductors (see, e.g. [7]). The dielectric phase transition in these systems is realized as magnetic (AF spin density wave (SDW), incommensurate with lattice period) phase transition in the conducting planes of doped compounds (normal state ($T_c < T_m = T^*$)). Though this transition begins well in the normal state (at $T \sim T^*$) but, due to intensive AF spin fluctuations, it is completed only at lower temperature, when AF spin-fluctuation scattering of conduction electrons disappears and modulated magnetic structure appears with quite sharp resistive drop and following then by superconducting transition. These two transitions are separated at total resistive transition curve by well known Bloch-Gruneisen (BG) curve, characteristic for phonon scattering in most metals [8]. The resistivity above BG-curve (normal state) is determined by scattering of conduction electrons via AF spin-fluctuations, while below BG-curve the phonons determine behavior of the system (including SC).

In such approach, the situation in sulfur hydrides, which compounds become to be metallic at such high pressure, seems to be quite similar to that in optimally-doped cuprates, pnictides and organic superconductors (Fig.1). The sharp drop of resistivity at 203 K can be attributed to magnetic (AF SDW) phase transition when AF spin fluctuation scattering of conduction electrons disappears and the resistivity is determined only

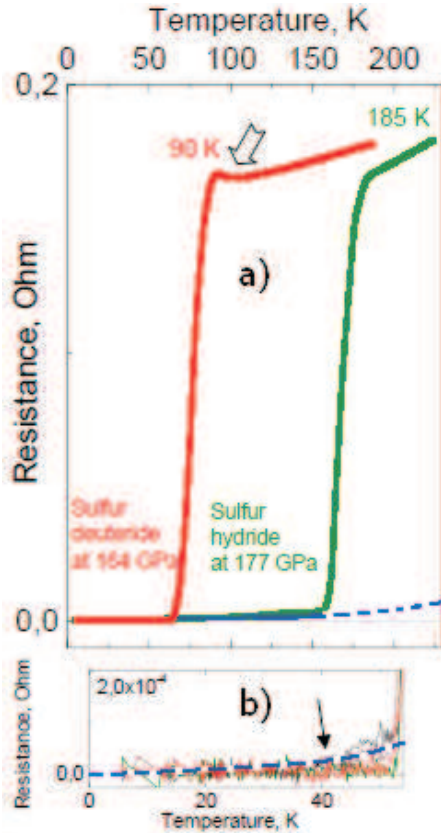


Рис. 1: The resistive transition curves for sulfur hydride (green curve) and sulfur deuteride (red line) at high pressure. (a) high temperature region: arrow indicates upturn part of resistive curve characteristic for insulating behavior; blue dashed curve schematically indicates the low-temperature part of BG (phonon) curve (for details, see text); b) low temperature region: blue dashed curve schematically demonstrates the intersection of BG (phonon) curve with tail of total resistive transition, determining the onset temperature of genuine SC transition T_c^{onset} (the data are from [1, 2]).

by scattering with phonons. The indication to formation of AF SDW in the normal state is more clear seen from resistivity measurements for deuterium hydride at high pressure (red curve in Fig.1a) when sharp resistive transition is preceded

by upturn in resistive dependence, which behavior is also characteristic for cuprates and pnictides (selenides) in underdoped case. As for magnetic (AF spin fluctuation) scattering of conduction electrons in sulfur hydrides then it can be provided due to magnetic properties of metallic hydrogen at such high pressure (see, e.g. [9, 10]). In this sense, because of ferromagnetism in metallic hydrogen [10], the situation seems to be closer to Fe-based HTSC. If so, then it can be proposed that hydrogen atoms in sulfur hydride system under high pressure are arranged antiferromagnetically (AF) leading to formation of AF SDW (cf. with [9]).

Since the Debye temperature Θ_D in these compounds is high enough (of the order of 5000 K in our estimations) the phonon part of resistivity at $T \leq 203K$ is relatively low (see schematic blue dashed curves in Fig.1 a,b) and point of its intersection with tail of total resistivity at lower temperature (corresponding to the genuine onset temperature T_c^{onset}) is difficult to determine correctly because of high enough noise level in resistivity measurements at low-temperature (see, Fig.1b). (Similar problem with correct determination of onset temperature of SC transition appears in cuprates and pnictides at isothermal resistivity measurements in high magnetic fields, see e.g. [6]). From Fig.1 the onset temperature of genuine SC transition can be estimated as near $T_c^{onset} \sim 40K$. Such estimation is consistent with observation of "a step with $T_c \sim 30 K$ " noted in supplementary information to [2]. Of course, to be more correct, it is necessary additional, more detailed study of transport and other properties of these compounds.

In other words, the above brief analysis of available resistive data for sulfur hydrides at high pressure demonstrates that in these compounds, at $T \sim 203K$, a sharp resistive transition, corresponding to the normal-state magnetic (AF SDW) phase transition, occurs, and only then the system can enter the SC state ($T_c < T_m$). The onset of the genuine, unconventional superconducting transition in H_2S seems to be located only noticeably lower on temperature ($T_c^{onset} \sim 40K$).

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